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(54) **INTEGRATED THRUST REVERSER ACTUATION SYSTEM**

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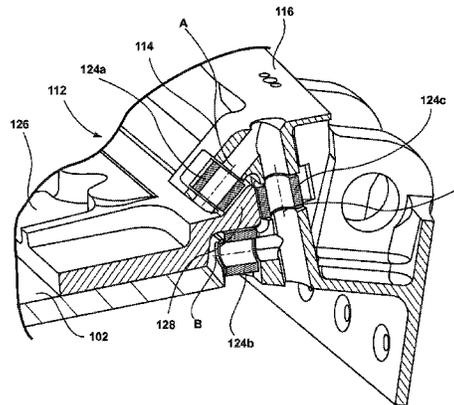
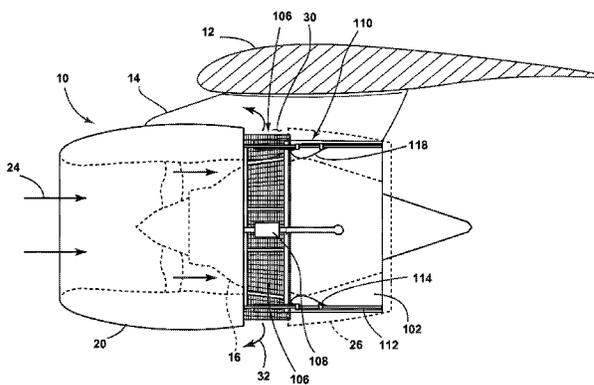
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(57) **ABSTRACT**

A turbofan engine having a turbine engine, a nacelle surrounding a portion of the turbine engine, and a thrust reverser. The thrust reverser comprises a movable control surface movable to and from a reversing position and a thrust reverser actuation system having at least one actuator operably coupled to the movable control surface to move the movable control surface into and out of the reversing position. A guide comprising a rail and a bogie having at least one rotatable bearing surface coupled to the rail for relative translational movement between the rail and bogie connects the turbine engine to the movable control surface such that operation of the at least one actuator moves the movable control surface by translation movement between the rail and the bogie.

**11 Claims, 5 Drawing Sheets**



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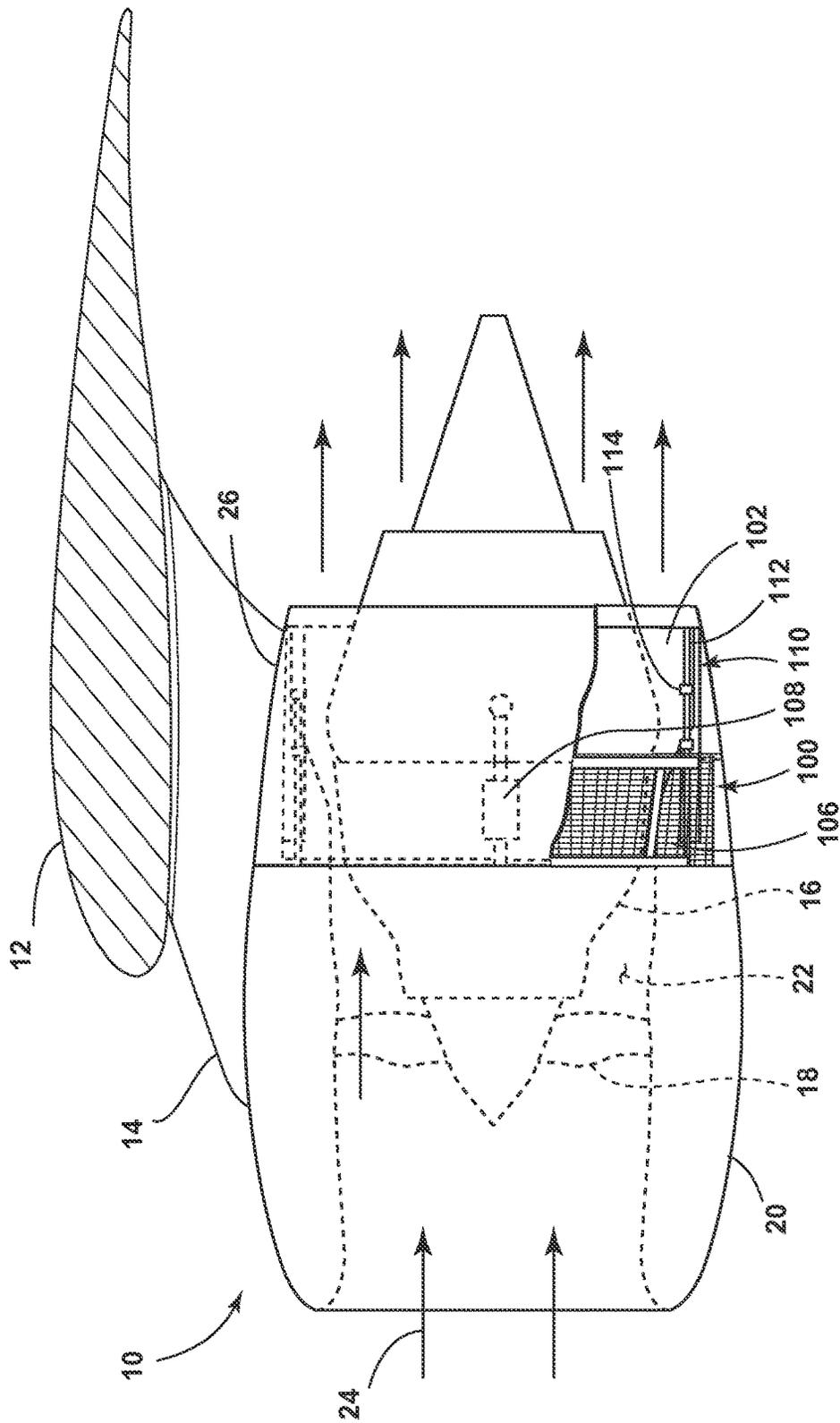


FIG. 1

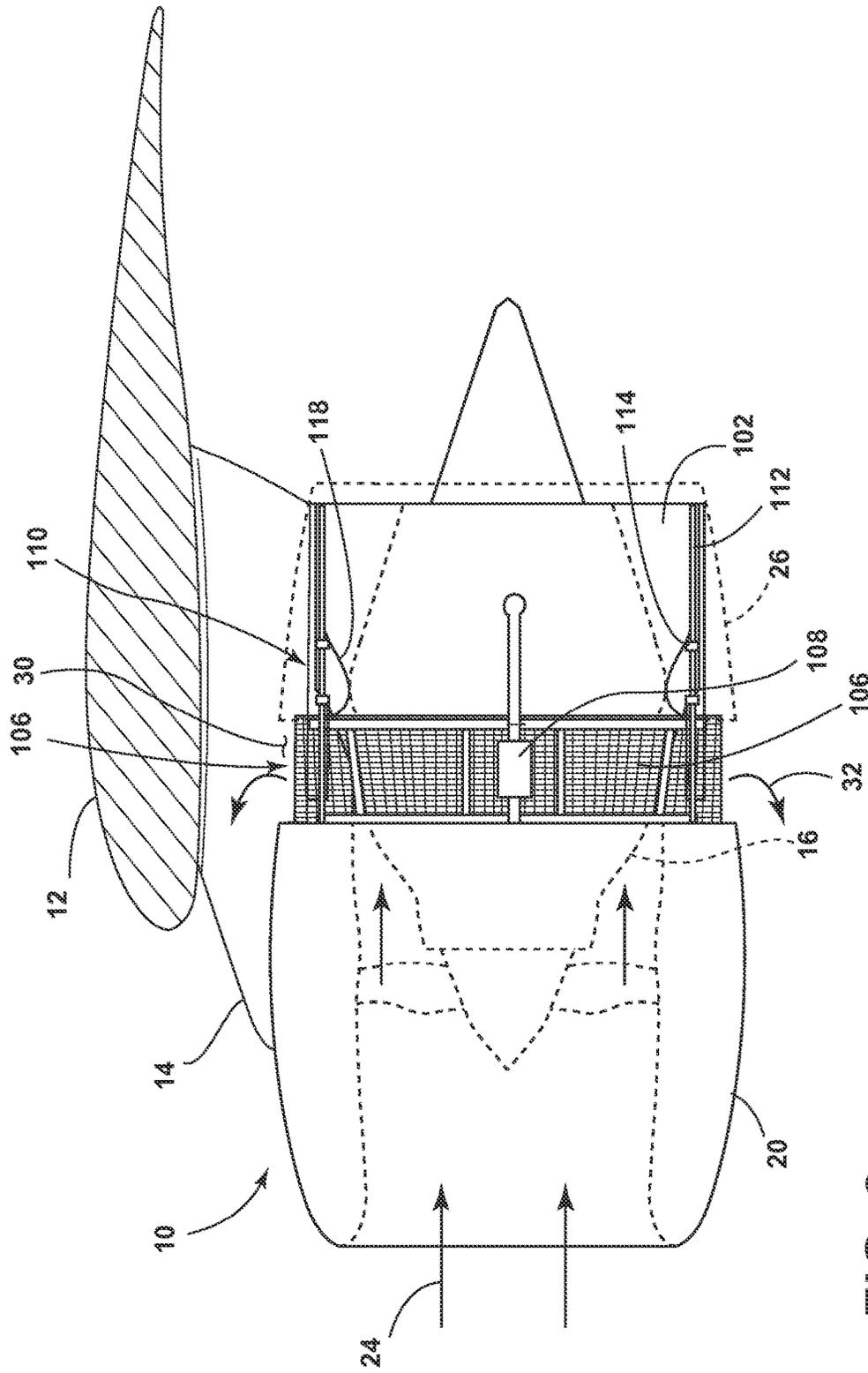


FIG. 2

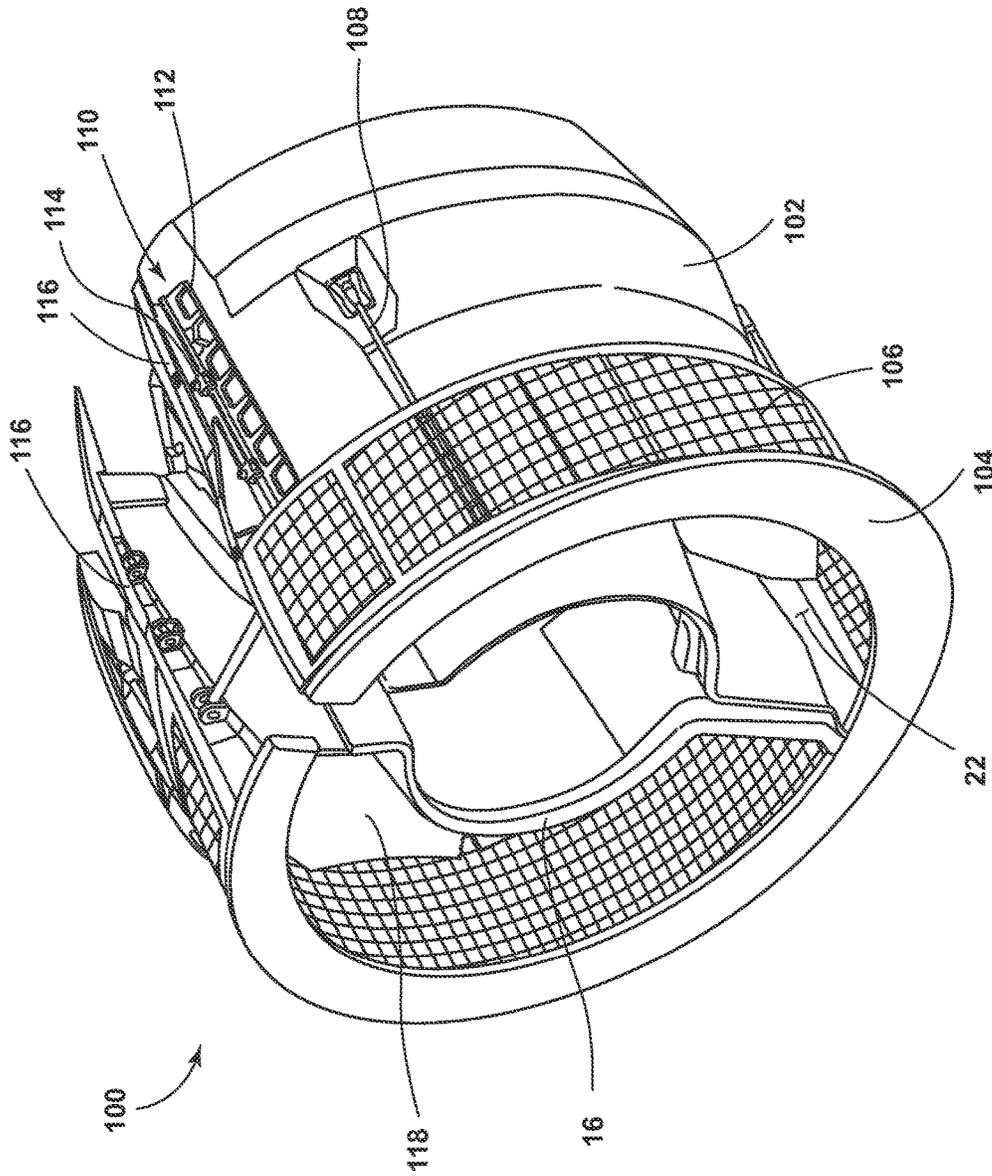


FIG. 3

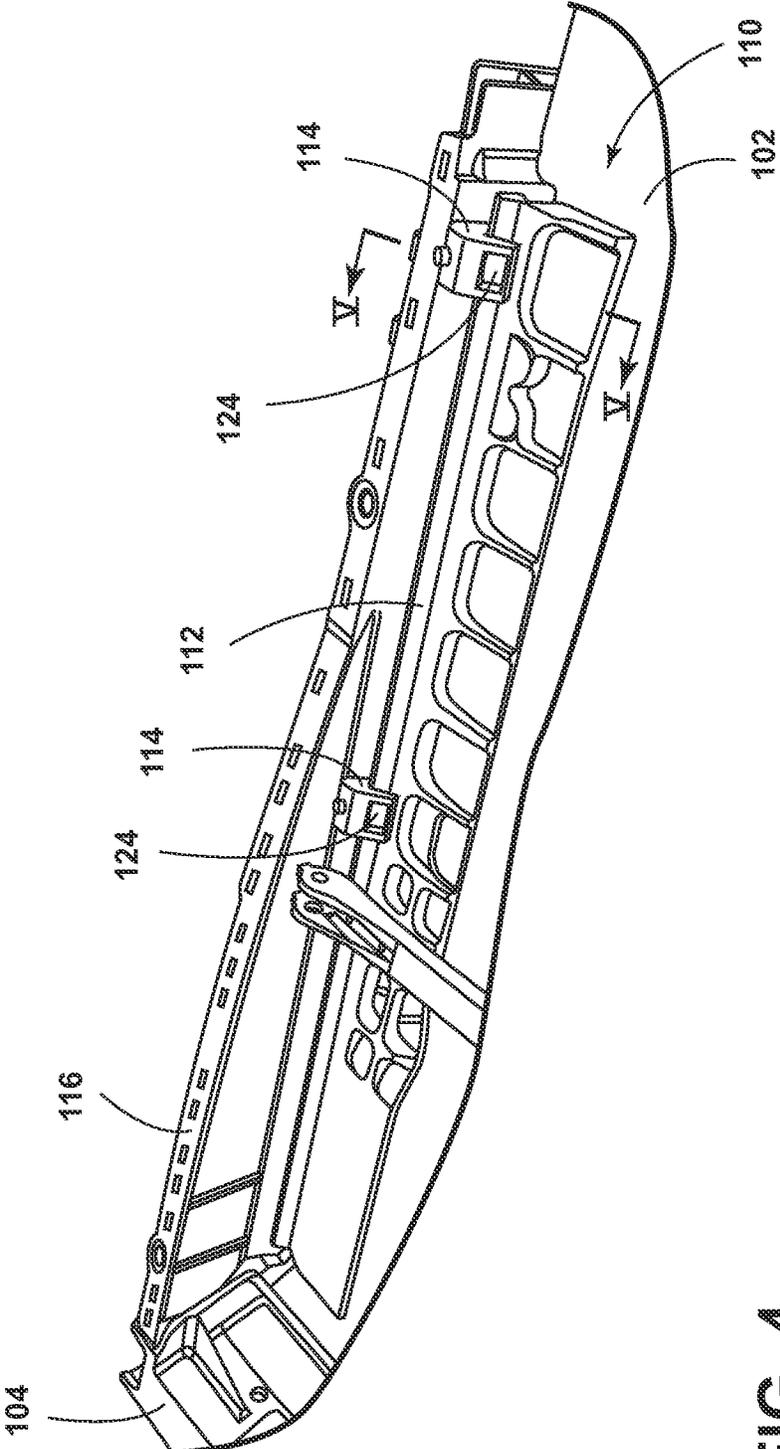


FIG. 4

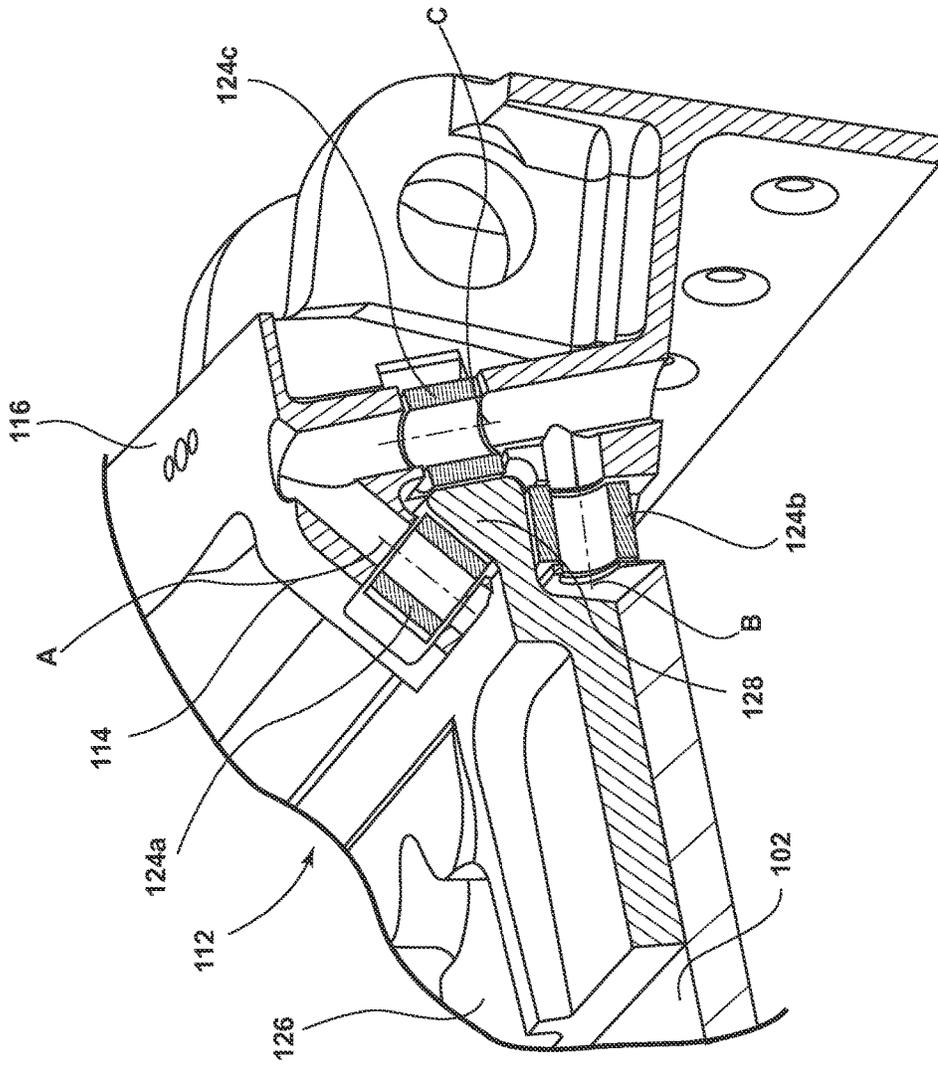


FIG. 5

## INTEGRATED THRUST REVERSER ACTUATION SYSTEM

### BACKGROUND OF THE INVENTION

Contemporary turbofan aircraft engines may include a thrust reverser system to assist in reducing the aircraft speed during landing. Typical thrust reversers include a movable control surface that when in the reversing position directs airflow through a thrust reverser cascade that reverses at least a portion of the airflow passing through the engine. Typically, the moveable control surface is guided by a low friction rail sliding within a guide channel in response to multiple actuators controlled by a mechanical synchronizing system to prevent binding between the rail and guide due to non-symmetric loading.

### BRIEF DESCRIPTION OF THE INVENTION

In one aspect, an embodiment of the invention relates to a turbofan engine having a turbine engine and a nacelle surrounding at least a portion of the turbine engine defining an annular bypass duct between the nacelle and the turbine engine and extending through the turbofan engine to define a generally forward-to-aft bypass air flow path. The turbofan engine further comprises a thrust reverser having a movable control surface and a thrust reverser actuation system. The movable control surface is movable to and from a reversing position where at least a portion of the bypass air flow is at least partially reversed. The thrust reverser actuation system comprises at least one actuator operably coupled to the movable control surface to move the movable control surface into and out of the reversing position. A guide comprising a rail and a bogie having at least one rotatable bearing surface coupled to the rail for relative translational movement between the rail and bogie connects the turbine engine to the movable control surface such that operation of the at least one actuator moves the movable control surface by translation movement between the rail and the bogie.

### BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is a schematic view of a wing, pylon and turbofan engine assembly.

FIG. 2 is a schematic view of the wing, pylon and turbofan engine assembly of FIG. 1 with an exemplary thrust reverser in the reversing position.

FIG. 3 is perspective view of a portion of turbofan engine assembly showing a thrust reverser.

FIG. 4 is perspective view of a portion of the thrust reverser of FIG. 3.

FIG. 5 is cross-sectional view taken along line V-V of FIG. 4.

### DESCRIPTION OF EMBODIMENTS OF THE INVENTION

FIG. 1 schematically illustrates a turbofan engine assembly 10 mounted to the wing 12 of an aircraft by an engine pylon 14. The turbofan engine assembly 10 comprises a turbine engine 16, a fan assembly 18, thrust reverser 100 and a nacelle 20. The nacelle 20 surrounds the turbine engine 16 and defines an annular airflow path or annular bypass duct 22 through the turbofan engine assembly 10 to define a generally forward-to-aft bypass airflow path as schematically illustrated by the arrow 24. The rear portion of the

nacelle 20 comprises an outer cowling 26. A portion of the outer cowling 26 has been removed for clarity.

The thrust reverser 100 is disposed beneath the outer cowling 26. The thrust reverser 100 includes at least one movable control surface 102, which is movable between stowed and reversing positions, and a thrust reverser cascade 106. At least one actuator 108 and at least one guide 110 may be coupled to the movable control surface 102 to move and guide the movable control surface 102 between the stowed and reversing positions.

The guide 110 comprises a rail 112 and a bogie 114 coupled to the rail 112. One of the rail 112 and bogie 114 is mounted to the turbine engine 16 and the other of the rail 112 and bogie 114 is mounted to the movable control surface 102 such that operation of the at least one actuator 108 moves the movable control surface 102 by translational movement between the rail 112 and the bogie 114.

In the embodiment shown, the bogie 114 is coupled to the turbine engine 16 and the rail 112 is coupled to the moveable control surface 102. Although, an opposite mounting arrangement is contemplated. When in the stowed position as illustrated, at least a portion of the movable control surface 102 is disposed between the thrust reverser cascade 106 and the annular bypass duct 22 to block airflow in the annular bypass duct from the thrust reverser cascade 106.

FIG. 2 schematically illustrates turbofan engine assembly 10 with the thrust reverser 100 in the reversing position. The movable control surface 102 has been illustrated as a slidable portion of an inner cowling that is capable of axial motion with respect to the forward portion of the nacelle 20 wherein the outer cowling 26, shown in phantom may also be coupled to the movable control surface 102 such that axial motion of the movable control surface 102 corresponds to axial motion of the outer cowling 26. In the reversing position, the movable control surface 102 limits the annular bypass area between the movable control surface 102 and the turbine engine 16, it also opens up a portion 30 between the movable control surface 102 and the forward portion of the nacelle 20 exposing the thrust reverser cascade 106 to at least a portion of the bypass airflow. The thrust reverser 100 changes the direction of the thrust force by directing at least a portion of the bypass airflow through the thrust reverser cascade 106, which has a plurality of vanes the orients at least a portion of the flow with a rearward direction, resulting in a reversal of at least some of the air flow as illustrated by the arrows 32. An optional deflector 118 or flap may be included to aid in directing the airflow path between the movable control surface 102 and the forward portion of the nacelle 20.

FIG. 3 illustrates the thrust reverser 100 portion of the turbofan engine assembly 10 of FIGS. 1 and 2 with the outer cowling 26 of the nacelle 20 shown in FIGS. 1 and 2 removed for clarity. The thrust reverser 100 may further comprise a stationary support ring 104, engine mount 116 and an airflow deflector 118.

The engine mount 116 extends in the generally forward to aft direction and comprises a rigid elongated structure. The engine mount 116 may be coupled to one of the turbine engine 16, the engine pylon 14 or the nacelle 20 shown in FIGS. 1 and 2. It may also be integrally formed with an engine pylon 14 and form mounting locations for the turbine engine 16, integrally formed with the turbine engine 16 and form mounting locations for the engine pylon 14 or may be integrally formed with the nacelle 20 and form mounting locations for the turbine engine 16 and/or engine pylon 14.

The stationary support ring 104 is rigidly connected to the forward portion of the engine mount 116 and extends on

either side of the engine mount **116** around a substantial portion of the circumference of the turbine engine **16** to provide rigid support about the circumference of the thrust reverser **100**.

The movable control surface **102** and thrust reverser cascade **106** extend on either side of the engine mount **116** around a substantial portion of the circumference of the turbine engine **16** defining an annular bypass duct **22**. The forward portion of the thrust reverser cascade **106** may be supported about its circumference by the stationary support ring **104**. The deflector **118** may be attached to or integrally formed with the movable control surface **102** to selectively allow or prevent airflow through the annular bypass duct **22**.

The actuator **108** extends in generally the forward to aft direction and may comprise two ends wherein a first stationary end may be attached to the stationary support ring **104** and the second extending end may be attached to the movable control surface **102**.

The guide **110** is disposed between the movable control surface **102** and the engine mount **116** wherein the bogie **114** is fixed to the engine mount **116** and the rail **112** is fixed to the movable control surface **102**.

The actuator **108** is operably coupled to the movable control surface **102** to move the movable control surface **102** into and out of the reversing position. When the movable control surface **102** is in the stowed position, the actuator **108** is retracted and the movable control surface **102** abuts the aft portion of the stationary support ring **104** blocking the inner circumferential surface of the thrust reverser cascade **106**. Also when in the stowed position, the deflector **118** is configured such that bypass airflow may pass through the annular bypass duct **22** between the turbine engine **16** and the inner circumferential surface of the movable control surface **102**.

Alternatively, the actuator **108** may include any apparatus capable moving the movable control surface **102** into and out of reversing position. For example, the actuator **108** may include but is not limited to, hydraulic actuators, pneumatic actuators, electric actuators, or rotation converters comprising gears, pulleys or the like.

When the movable control surface **102** is in the reversing position as illustrated, the actuator **108** is extended and the movable control surface **102** is spaced apart from the stationary support ring **104** exposing the inner circumferential surface of the thrust reverser cascade **106**. Also when in the reversing position, the deflector **118** is configured such that bypass airflow may not pass through the annular bypass duct **22** between the turbine engine **16** and the inner circumferential surface of the movable control surface **102**, forcing the airflow through the thrust reverser cascade **106** which reverses at least a portion of the bypass airflow.

When the movable control surface **102** is moved from one of the stowed or reversing position to the other of the stowed or reversing positions, the rail **112** fixed to the movable control surface **102** and the bogie **114** fixed to the engine mount **116** provide for translational movement of the movable control surface **102** in the forward and aft direction.

FIG. 4 shows a close up view of a portion of FIG. 3 to better illustrate the guide **110** disposed between the movable control surface **102** and engine mount **116**. The guide **110** may comprise two bogies **114** affixed to and spaced apart along the engine mount **116** so as to provide two points of contact to the rail **112** and prevent pivoting about a bogie **114** when the movable control surface is moved in the forward or aft directions. Each bogie **114** comprises a rotatable bearing surface **124** in communication with the rail **112**. When the movable control surface **102** is moved in the

forward or aft directions, the only points of contact between the rail **112** affixed to the moveable control surface **102** and the bogies **114** affixed to the engine mount **116** are the rotatable bearing surfaces **124** so as to provide for translational movement between the rail **112** and bogie **114**, eliminating sliding friction and imparting only rolling friction between the rail **112** and bogie **114**. While two bogies **114** are illustrated, more bogies **114** are contemplated. It is also possible for a single bogie **114** to be used as long as the relative racking or binding between the bogie **114** and rail **112** can be prevented, which may be possible for shorter travel distances and/or more bogie/rail combinations are provided about the engine.

FIG. 5 shows a cross sectional view taken along V-V of FIG. 4. The rail **112** may comprise a mounting portion **126** for mounting the rail **112** to the movable control surface **102** and a guiding portion **128** for coupling the bogie **114** to the rail **112**. The guiding portion **128** of the rail **112** may extend in generally forward to aft direction as illustrated in FIG. 4 and may have a length configured to span the distance between the bogies **114** and allow for the translation movement of the moveable control surface **102** such that the guiding portion **128** does not lose contact with the either bogie **114** during said translational movement.

According to one embodiment, the guiding portion **128** may form three planar surfaces each lying on three distinct intersecting planes wherein all three distinct intersecting planes are perpendicular to a common cross section plane defined by the cross sectional line V-V illustrated in FIG. 4. The three planar surfaces of the guiding portion **128** are arranged to communicate with three rotatable bearing surfaces **124a**, **124b**, **124c** housed in the bogie **114**. The rotatable bearing surfaces **124a**, **124b**, **124c** are shown without axles for clarity, however, it will be understood that any axle or the like well-known in the art may be used to enable the rotation the rotatable bearing surface **124a**, **124b**, **124c** about rotation axes A, B, C respectively. The three rotatable bearing surface **124a**, **124b**, **124c** are arranged to provide opposing bearing forces to the three planar surfaces of the guiding portion **128** such that the rotatable bearing surfaces **124a**, **124b**, **124c** prevent separation of the rail **112** and bogie **114** while providing translational movement between the rail **112** and bogie **114**.

When an actuator **108** imparts a force on the movable control surface **102** in either the forward or aft directions, the three planar surfaces of the guiding portion **128** contacting the outer surface of the rotatable bearing surfaces **124a**, **124b**, **124c** induce rotation of the rotatable bearing surfaces **124a**, **124b**, **124c** about rotation axes A, B, C, providing for translational movement between the actuating rail **112** and the stationary bogie **114** in the forward or aft directions. While three planar surfaces and three rotatable bearing surfaces **124a**, **124b**, **124c** are illustrated, less or more rotatable bearing surfaces **124** are contemplated. It is also possible for a single rotatable bearing surface **124** to be used as long as the rotatable bearing surface **124** prevents separation between the rail **112** and bogie **114** and provides translation movement between the rail **112** and bogie **114**, which may be possible with various rail **112**, bogie **114** and rotatable bearing surface **124** configurations.

In another embodiment, the bogie **114** may be mounted the moveable control surface **102** and the rail **112** may be mounted to the engine mount **116** wherein the bogie **114** comprises at least one rotatable bearing surface coupled to the rail **112** for relative translational movement between the rail **112** and bogie **114**.

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The embodiments described above provide for a variety of benefits including that a the rail and bogie having at least one rotatable bearing surface provide for low friction translational movement between the engine mount and the moveable control surface such that binding, wear, number of actuators and actuation force may all be reduced.

To the extent not already described, the different features and structures of the various embodiments may be used in combination with each other as desired. That one feature may not be illustrated in all of the embodiments is not meant to be construed that it may not be, but is done for brevity of description. Thus, the various features of the different embodiments may be mixed and matched as desired to form new embodiments, whether or not the new embodiments are expressly described. All combinations or permutations of features described herein are covered by this disclosure.

This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A turbofan engine comprising:

a turbine engine;

a nacelle surrounding at least a portion of the turbine engine and defining an annular bypass duct between the nacelle and the turbine engine defining a forward-to-aft bypass air flow path;

a thrust reverser having at least one movable control surface, movable to and from a reversing position, where at least a portion of a bypass air flow is at least partially reversed, wherein the at least one movable control surface is a slidable portion of an inner cowling of the nacelle capable of an axial motion with respect to a forward portion of the nacelle, and in the reversing position limits an annular bypass area between the at least one movable control surface and the turbine engine;

a thrust reverser actuation system having at least one actuator operably coupled to the at least one movable control surface to move the at least one movable control surface into and out of the reversing position; and

a guide comprising a rail having a guiding portion including three planar surfaces lying in three distinct, non-parallel, intersecting planes, wherein the three distinct, non-parallel, intersecting planes are distinct from one another and are perpendicular to a common cross section plane and wherein each plane of the three distinct, non-parallel, intersecting planes intersects the other two planes, and a bogie having three bearing surfaces coupled to the rail at the three planar surfaces for relative translational movement between the rail and the bogie;

wherein one of the rail and the bogie is mounted to the turbine engine and other of the rail and the bogie is mounted to the at least one movable control surface such that an operation of the at least one actuator moves the at least one movable control surface by translation movement between the rail and the bogie; and

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wherein the three bearing surfaces each comprise a rotatable bearing surface, each rotatable bearing surface in contact with and arranged to provide opposing bearing forces to a corresponding one of the three planar surfaces to prevent separation of the rail and the bogie during translational movement between the rail and the bogie.

2. The turbofan engine of claim 1, wherein the nacelle comprises a cowling portion defining the at least one movable control surface.

3. The turbofan engine of claim 2, wherein the rail is provided on the cowling portion and the bogie is provided on an engine mount.

4. The turbofan engine of claim 3, wherein the bogie is fixedly mounted to the engine mount.

5. The turbofan engine of claim 4, further comprising an engine pylon forming the engine mount.

6. The turbofan engine of claim 1, further comprising an engine pylon and one of the rail and the bogie is mounted to the engine pylon and other of the rail and the bogie is mounted to the at least one movable control surface.

7. The turbofan engine of claim 6, wherein the bogie is fixedly mounted to the engine pylon.

8. The turbofan engine of claim 1, wherein in the reversing position, the at least one movable control surface exposes a thrust reverser cascade, between the at least one movable control surface and the forward portion of the nacelle, to at least the portion of the bypass air flow.

9. A thrust reverser comprising:

at least one movable, control surface that includes a slidable portion of an inner cowling of a nacelle, movable to and from a reversing position with respect to a forward portion of the nacelle, wherein the nacelle surrounds at least a portion of a turbine engine and defines an annular bypass duct between the nacelle and the turbine engine defining a forward-to-aft bypass air flow path;

a thrust reverser actuation system having at least one actuator operably coupled to the at least one movable control surface to move the at least one movable control surface into and out of the reversing position; and

a guide that includes a rail having a guiding portion including three planar surfaces lying in three distinct, non-parallel, intersecting planes, wherein the three distinct, non-parallel, intersecting planes are distinct from one another and are perpendicular to a common cross section plane and wherein each plane of the three distinct, non-parallel, intersecting planes intersects the other two planes, and a bogie having three rotatable bearing surfaces coupled to the rail at the three planar surfaces for relative translational movement between the rail and the bogie;

wherein one of the rail and the bogie is mounted to the turbine engine and the other of the rail and the bogie is mounted to the at least one movable control surface such that operation of the at least one actuator moves the at least one movable control surface by translation movement between the rail and the bogie, and in the reversing position, the at least one movable control surface limits an annular bypass area of the annular bypass duct formed between the at least one movable control surface and the turbine engine; and

wherein the three bearing surfaces each comprise a rotatable bearing surface, each rotatable bearing surface in contact with and arranged to provide opposing bearing forces to a corresponding one of the three planar

surfaces to prevent separation of the rail and the bogie during translational movement between the rail and the bogie.

**10.** The thrust reverser of claim **9**, wherein in the reversing position, at least a portion of a bypass air flow is at least partially reversed. 5

**11.** The thrust reverser of claim **10**, wherein in the reversing position, the at least one movable control surface exposes a thrust reverser cascade, between the at least one movable control surface and the forward portion of the nacelle, to at least the portion of the bypass airflow. 10

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